Appendix A: Regional Supply Water Systems in SATIM-W

Nomenclature adopted for the codes in the Reference Energy-Water System (REWS) diagrams

To organize the REWS it is essential to adopt a naming convention scheme that enables the user to easily recognize the nature and role of each of the components. To accomplish this the REWS component names are assembled from the acronym components listed below.

Regional WSR identifiers:

A: Limpopo WMA (Waterberg)

B: Olifants WMA (Central Basin)

C: Upper Vaal WMA (Central Basin)

D: Orange WMA (Northern Cape/Karoo)

K: Karoo aquifer system

R: Area in the vicinity of the Richards Bay Coal Export Terminal

WMIN: Water supply system

Ux: Delivery (Transmission) of Water

UPS: Upstream of Water Delivery

WT: Water treatment technology

WAx: Scheme water commodity
where x designates water quality subcategory

Px: Primary/Raw water (e.g. Coal washing)
where x designates the water quality subcategory (x = 0, 1)

Hx: High quality water (e.g. Boiler feedwater)
where x designates the water quality subcategory (x = 1)

Note: while only one subcategory (x=1) is implemented in the model the approach allows for the flexibility to include additional categories.

Example naming structure:

WA-P1-D: the volume of primary quality water, i.e. generic boiler feedwater (1), delivered to a process or technology in region D.

UPSWA-H1-D: the volume of high quality water with no associated delivery cost in region D.

U1WA-H1-D: the cost for a specific mode of delivery (e.g. by pipeline) attributed to the water commodity in region D.

Note: Region D has different delivery modes for the technologies represented and this results in a sub-regional water supply system that is differentiated by an additional regional index. The sub-regional supply systems are labelled D1, D2 and D3. The remaining regions have supply and delivery costs combined which simplifies the implementation and naming conventions adopted.

Regional water supply systems and individual schemes

Each regional water supply system is distinguished by an appended region code. The nomenclature is adopted from the naming conventions introduced in Task 1. Where possible the supply and delivery (transmission) costs as elaborated in Task 1 are combined to simplify the overall model implementation.

For region D this was not possible as different delivery costs are given for the shale gas and CSP sectors. Therefore delivery is modelled as a distinct component, as explained below.

- It is likely that additional gas related energy sector development in the region would occur with shale-gas mining. As shown in the RES diagrams, this may include GTL, OCGT and CCGT technologies. Since CSP technologies are located in the North Cape, delivery costs given for shale-gas mining are include for these technologies as it is assumed that they would be collocated.

- The RES for region D is more complex than the other regions because of the multiple delivery options. This is especially the case for shale-gas mining which has three delivery routes: bulk pipeline, truck; and onsite groundwater use. In the model this is represented as modal shares which can vary in time. For example, delivery by truck would most likely be the main delivery route in the initial development phase of shale gas sector with a bulk pipeline potentially reducing the requirement for vehicular transport as the sector matures and additional energy supply sector technologies emerge such as gas-fired electricity generation and/or GTL production.

- For the above reasons, as depicted in the RES diagram for Region D, the water supplied to consumers is split into sub regional systems: D1 (CSP region), D2 (shale gas energy technologies such as GTL and CCGT) and D3 (shale-gas mining).

- Each scheme has a water quality commodity attribute with the existing supply system set as the reference (level 0).

Parameterisation of Water Supply Technologies

The model parameters for implementing the regional water supply systems in SATIM-W are summarised below in Table A-1. For the treatment technologies, the simplified expression is included as an alternative should a levelised cost be preferred for certain cases. This may occur if a treatment cost is relatively small and would apply to primary treatment. As previously discussed Region D requires the delivery component to be separated.

Table A-1 SATIM-W parameters characterising a water supply system.

TIMES parameters	Scheme Supply & Delivery	Treatment
Time varying parameters		
NCAP_COST	Capital (ZAR/Mm^3)	Capital (ZAR/Mm^3/annum)
NCAP_FOM	Fixed OM (ZAR)	Fixed OM (ZAR)
PRC_ACTFLO	Energy commodity Electricity or Diesel (kWh/m^3) or (L/m^3)	Energy commodity Electricity (kWh/m^3)
ACT_COST[1]	In SATIM-W included as a FOM cost	n/a
ACT_BND	Yield (Mm^3)	n/a
Time invariant parameters		
TOP-IN (Commodity input)	Electricity or Diesel	Electricity
TOP-OUT (Commodity output)	W[i]1 (Mm^3)	W[i]H1 (Mm^3)
Commodity usage :	(simplified alternative for Primary Treatment)	
FLO_COST	n/a	Unit Water Cost (ZAR/Mm^3)

[1]Variable costs are combined with FOM costs to ensure that the model is committed to a particular scheme once selected. This is necessary due the varying construction time of individual water supply projects (schemes) and the demands that may occur.

Note that some schemes have construction lead times. For example, this applies to the case of the use of Acid Mine Drainage as an interim option should the cheaper Vaal–Usutu scheme be unavailable at such a time when the DWA water demand forecast requires additional supply for the Vaal region. The construction lead times are taken from the DWA study of the marginal cost of water for future supply options that informs the analysis of Task 1.

Water Supply Costs

The net Unit Water Cost (UWC) for an increase in regional water supply (as derived from Task 1) are displayed in Table A-2. The net UWC includes both supply and delivery for Regions A to C. For Region D, the supply and delivery costs are shown for the different modes of supply and delivery.

As depicted in Figure A-1, due to the construction lead times, the marginal costs may not be in ascending order. The figure is however illustrative as the selection of the next scheme is dependent on the projected regional demand which may vary by scenario.

Table A-2 Summary of regional water supply costs (prices in ZAR 2010).

Region	Regional supply ID	Scheme description	Delivery mode	Net UWC (ZAR/m^3 per annum)	Cumulative supply (Mm^3 per annum)
Lephalale (Limpopo)	WMIN-A1	Mokolo Croc Phase 1	Gravity pipeline from Lephalale	18.11	14
	WMIN-A1	Mokolo Croc Phase 2	Included in net supply cost	30.73	54
	WMIN-A3	Reuse and transfer from Vaal		27.46	180
	WMIN-A4	Transfer from Vaal		14.03	270
	WMIN-A6	Desalination of seawater	Included in net supply cost	33.67	(unlimited)
Upper Olifants	WMIN-B1	Olifants Dam	Pipeline from Olifants Dam	17.54	55
	WMIN-B2	Use of acid mine drainage	Reuse AMD - pipeline from dam in Upper Olifants	8.74	86
	WMIN-B3	Transfer from Vaal River	Import Vaal Dam - pipeline from dam in Upper Olifants	10.43	276
	WMIN-B5	Desalination of seawater	Included in net supply cost	24.47	(unlimited)
Vaal	WMIN-C1	LHWP II (Polihali DAm)	No additional cost	3.76	437
	WMIN-C2	Use of AMD		5.85	475
	WMIN-C3	Thukela-Vaal Transfer		7.47	997
	WMIN-C4	Orange-Vaal transfer		5.95	1514
	WMIN-C5	Mzimvubu transfer scheme		11.26	2145
	WMIN-C7	Desalination of seawater		15.58	(unlimited)
Lower Orange	WMIN-D1U1	Boskraai Dam	CSP pipeline: Included in plant Investment cost	0.61	227
	WMIN-D2U1	Mzimvubu kraai Transfer		6.28	392
	WMIN-D3U1	Desalination of seawater		22.43	(unlimited)
Lower Orange	WMIN-D1U2	Boskraai Dam	Hydraulic fracturing: pipeline	122.59	227
	WMIN-D2U2	Mzimvubu kraai Transfer		128.26	392
	WMIN-D3U2	Desalination of seawater		144.42	(unlimited)
Lower Orange	WMIN-D1U3	Boskraai Dam	Hydraulic fracturing: road transport	113.99	227
	WMIN-D2U3	Mzimvubu kraai Transfer		119.66	392
	WMIN-D3U3	Desalination of seawater		135.81	(unlimited)
Lower Orange	WMIN-DK0	Hydraulic fracturing - groundwater	None applicable	2.27	0.1[#]

[#]Annual supply from aquifer

Note:

- Seawater desalination was chosen as the ultimate scheme supply. The alternate option of a transfer from the Zambesi River was not included due to potential water security concerns.
- The electricity tariff for pumping was adjusted to estimate the industrial tariff at ca. ZAR 50c/kWh.
- Road transport diesel consumption was estimated at 2MJ/tonne-km with a calorific value of diesel given as 35.94 MJ/L and a load factor of 50%.
- The costs for pumping and road transport are estimates and their actual value will depend on the demand for water in the model as electricity and diesel consumption are explicitly modelled as input commodities in terms of kWh/m^3 and Litres/m^3 of water delivered (although in TIMES the native units are PetaJoules/Mm^3).

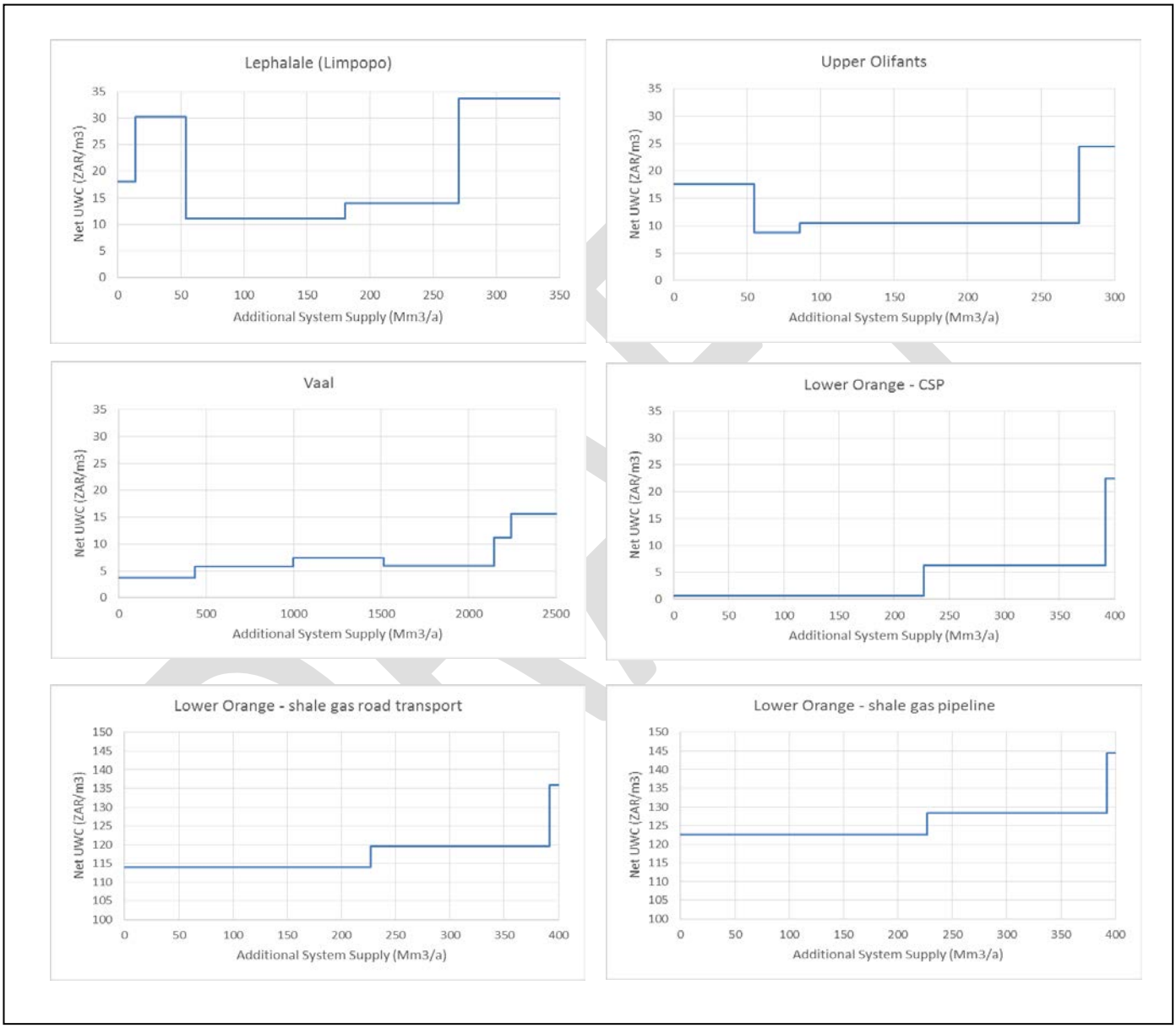

Figure A-1 Summary of costs for an increase in regional water supply.

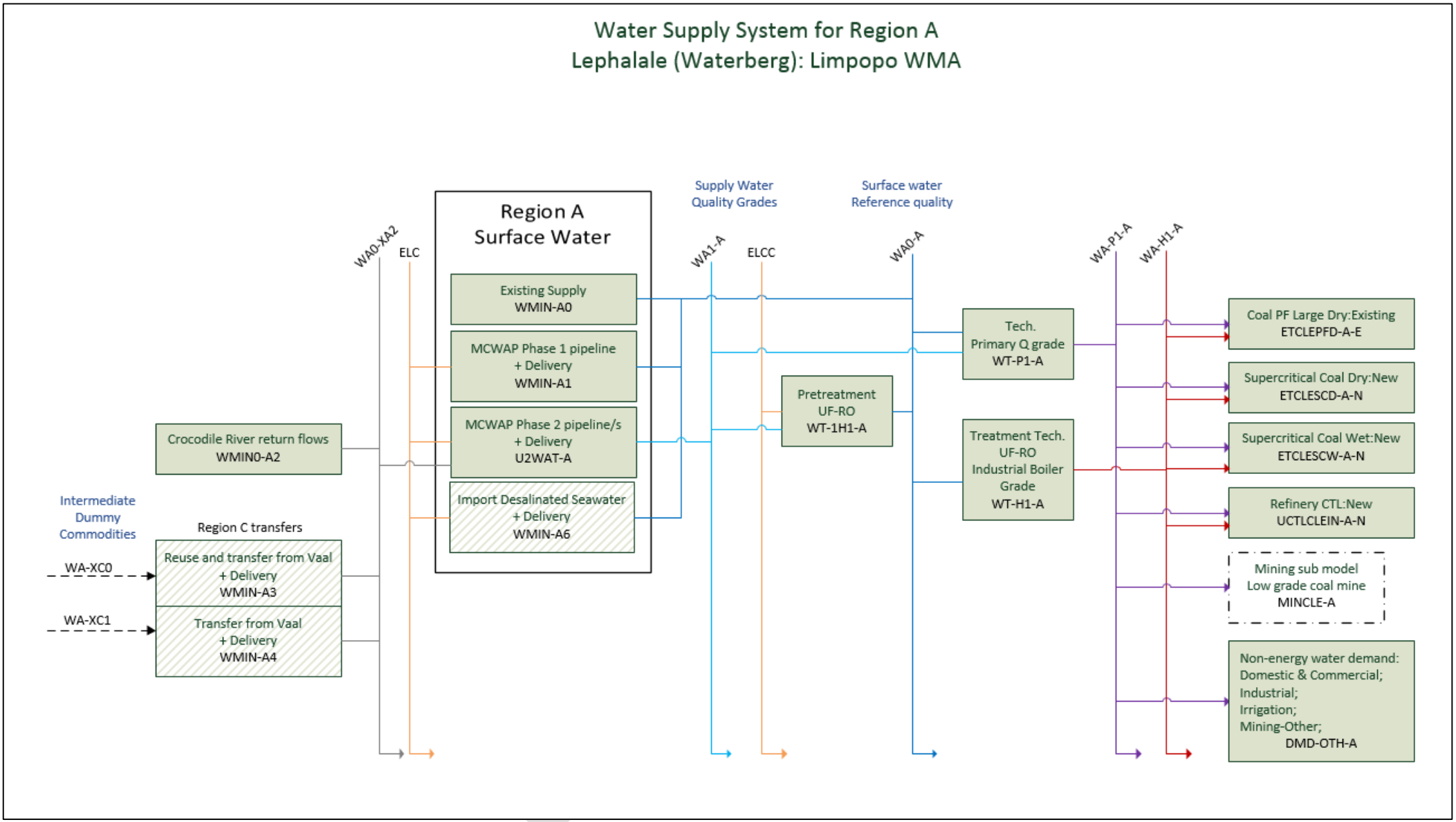

Figure A-2: The SATIM-W water supply system for Region A.

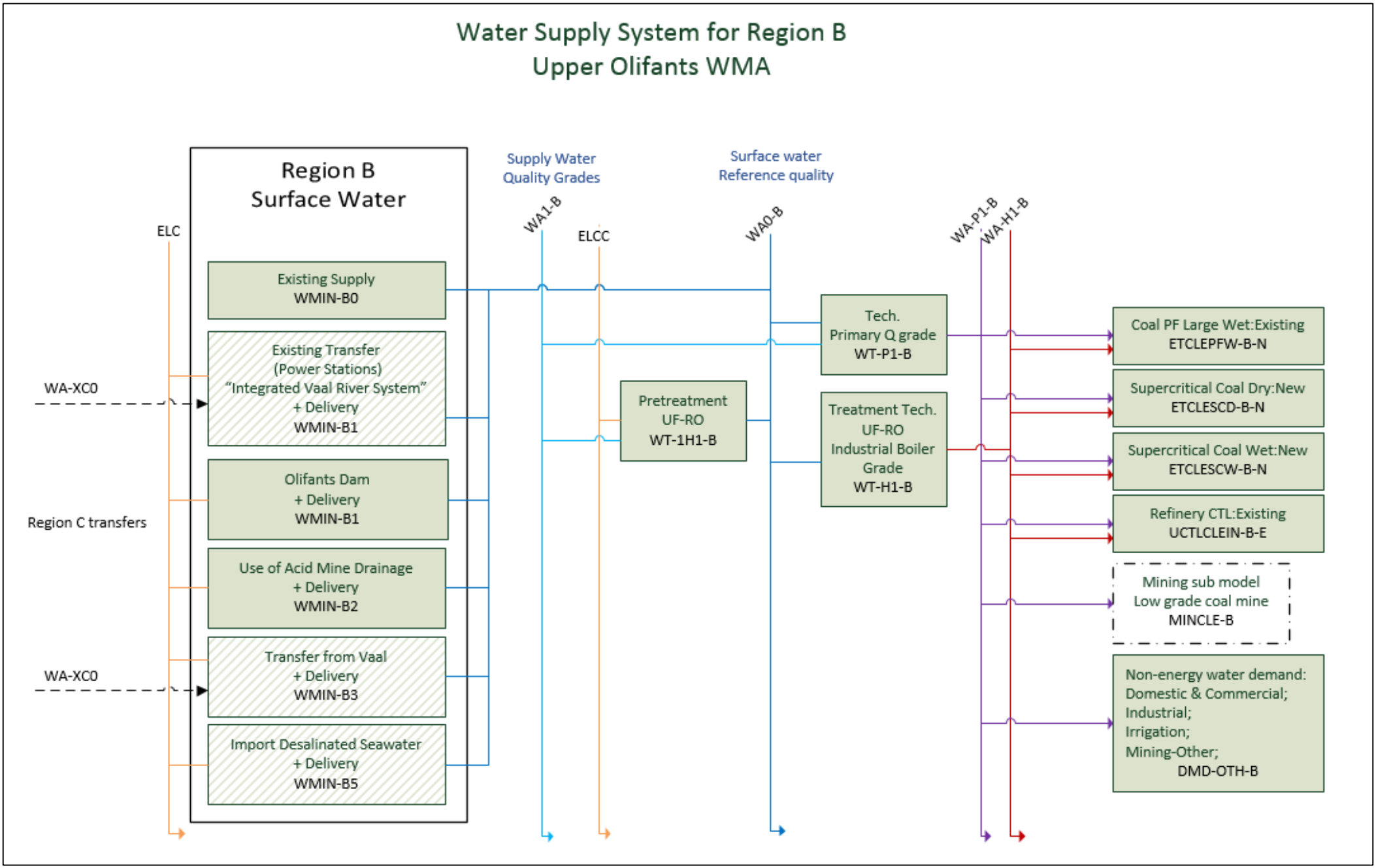

Figure A-3: The SATIM-W water supply system for Region B.

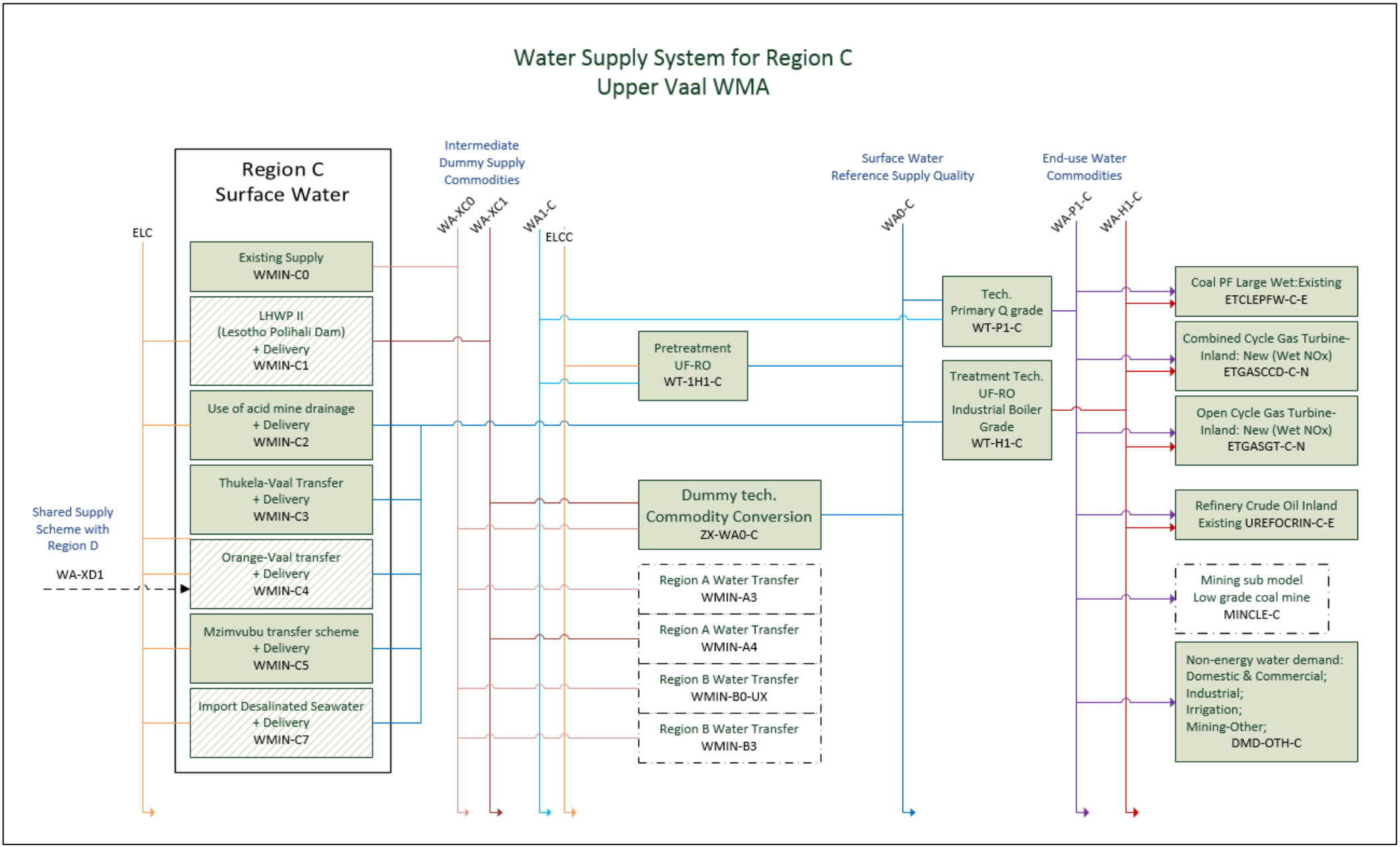

Figure A-4: The SATIM-W water supply system for Region C.

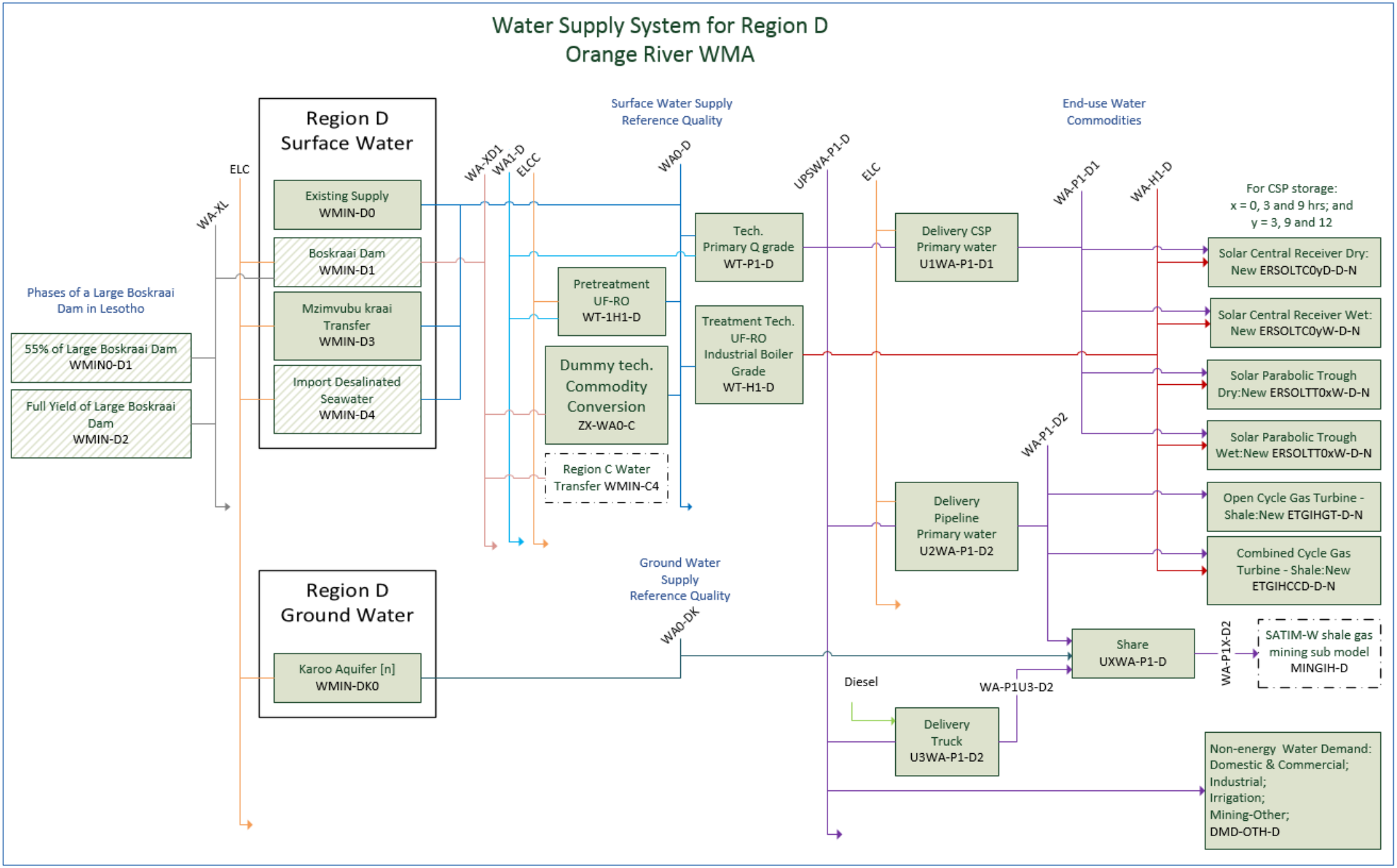

Figure A-5: The SATIM-W water supply system for Region D.